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EDF's PERFORMANCE FEEDBACK SYSTEM AT WORK: THE CASE OF THE "PIQUAGE"

I. EDF's PERFORMANCE FEEDBACK SYSTEM AS A PROCESS OF ORGANIZATIONAL LEARNING

Nuclear power plants represent a highly defined technology comprised of many interdependent systems. These systems are based on historically well-known, mechanical techniques to create and dissipate heat used to power an electrical generator. In effect, a nuclear power plant is one very large machine, where a lot of little things may go wrong: washers wear out, pipe welds crack from vibration, maintenance workers forget to tighten screws and bolts, or fire detectors become dysfunctional due to radiation exposure. The challenge in operating nuclear power plants is that the interdependency between human and technical systems is complex which may lead to unanticipated outcomes.

EDF's system of nuclear power generation is based on the premise that by having many plants of the same size and basic design, knowledge of how such big machines work efficiently and safely can more easily be accumulated over time. This knowledge can identify and solve generic problems so that the uncertainties in running such machines can be reduced. Since nuclear power plants are designed on the basis of known technical and regulated systems, periodic inspections can be made on various system components through measuring and/or calibrating tangible characteristics. Machines that must perform within certain standards or tolerances

or under specific atmospheric conditions, such as temperature and humidity, can be monitored by testing those factors that affect their performance. For example, to determine the probability that leakage will occur at a pipe joint, the thickness of the pipe weld can be measured.

Such tests and equipment calibrations generate knowledge of actual operating conditions which can then be compared with design or regulated conditions. When there is a gap between them, that knowledge or information may be disseminated and action taken to rectify the situation. Corrective action alters the probability that unforseen and unwanted events may occur, thereby improving safety and reducing the risk of an unplanned shutdown.

EDF staff refer to the process of creating, disseminating, and then utilizing knowledge about performance to improve the efficiency of the machine is known as "retour d'experience". This phrase may be loosely translated as "performance feedback" system. While one may look at how performance feedback is used to increase the efficiency of a given nuclear power plant, EDF, as an organization system, is designed to enhance the sharing and application of information that comes from the performance of many plants. The assumption is that knowledge about how to engender safe performance is created through performance, or operations, itself. That is, by operating 54 nuclear power plants, EDF is creating a repository of knowledge about plant operations that can be used not only to monitor a wide

range of factors that induce safe and efficient performance but to anticipate unplanned events as well.

EDF has created structures and processes that comprise this feedback system. Through lessons learned about past problems, EDF personnel are able to identify defects or limitations of equipment, either in its design, construction, or maintenance. Preprogrammed steps are then followed to maintain systems or create conditions that lower the risk of system failure. In effect, through operational experience, EDF builds its repertoire of preventive maintenance to reduce problems or defects that lead to system failure. Operational experience may also lead to redesign or system modifications.

The aim of a performance feedback system is to create and disseminate knowledge of performance in order to increase efficiency. Management's intent is to socialize staff to value the identification and sharing of problems so that solutions may be found before the problem or defect has significant consequences. This orientation propagates a "safety culture" which predisposes staff to think about the ramifications and repercussions of undetected or unreported problems in the machine. Management claims that EDF's organizational culture does not value retribution for staff who are seen to be either bearers of bad news or the proximate cause of an event. In fact, defects or problems may not

stem from one simple root cause that can easily be attributed to the performance of a single individual.

EDF's process of decision-making which relies on the collective knowledge and expertise of groups of employees, creates an environment in which no one individual is solely accountable for an action taken. For example, what may appear to have been a flaw in the design of a piece of equipment, such as a pump, may not be associated with an individual designer, since the pump was probably designed by a team of engineers. Subsequent investigation may also reveal that the problem was neither in design nor construction, but that somehow the communication between these two staff groups was inadequate, thus leading to a faulty pump.

The nature of nuclear power plant technology and the design and culture of EDF as a network of similar, interconnected plants, creates an organizational environment that establishes certain preconditions for learning. For example, staff are expected to act on the basis of recognizing the interdependencies between plants and how the experience of one plant may be a barometer for others. Whenever a problem is identified at one EDF plant, it raises staff concern that the same problem exists at a similar plant.

Although there are social and other cultural differences between EDF's geographically scattered nuclear power plants, there is a similarity in plant design and operations which creates a potential

for generating shareable lessons. One of the challenges for EDF is to determine whether a particular defect that occurs at a plant is unique to that plant or is a generic problem that should be of concern to all other similar plants. The type of interventions and processes used to explore and address generic versus idiosyncratic problems are quite distinct. Understanding and solving generic problems involves a greater number of interorganizational and intergroup exchanges than problems that can be easily and appropriately addressed at a given plant. The case of the "piquage" (French for nozzle) demonstrates how EDF's processes for sharing information and reacting to performance lessons actually functions.

II. THE CASE OF THE PIQUAGE

EDF has 20 nuclear power plants whose designed electrical output is rated at 1,300 megawatts (MW) per hour. These plants were built in two design series after lessons from the operations of the first series led to a few design changes in the second. Overall, the plants are of relatively similar design.

Every EDF plant must be shut down periodically to replace and move some of the fuel rods in the reactor vessel and to perform maintenance tasks that cannot be accomplished while the reactor is engaged. In the summer of 1991, one of Belleville's two 1,300 MW plants was shut down for this periodic maintenance and refueling.

After all the maintenance tasks were completed and the reactor building sealed, plant staff, in accordance with procedures, ran a series of tests to insure that all systems were operative. Among these were tests of the plant's many redundant safety systems.

During this series of tests, staff must check fluid pressure in an injection pump. On June 22, while this test was underway on Belleville 2's spray containment safety system, a rondier (watchman) noticed sweating at the end of a nozzle that is welded onto a principal pipe. Subsequent investigations, made through visual examination of a dye test that penetrates into the pipe, indicated that there were cracks that went down from the nozzle and through the wall of the connecting pipe. These test results suggested that, under emergency conditions, the safety system could not be relied upon to function properly.

The rondier shared his observation with the shift supervisor, who conveyed them to site staff responsible for safety. Since this defect was noticed on a Saturday, there were few plant staff around to be notified. Consequently, the safety engineer on duty first informed the on-call team for Belleville, then EDF's on-call team in Paris from Exploitation Production Nucleaire (EPN), and then sent messages to all other similar plants notifying them of the problem that had been discovered.

The following Monday, EPN informed the site superintendents at all of EDF's 1,300 MW units that they should inspect the connections between the nozzles and pipes on the same safety system where Belleville had first identified the leakage. The same day, maintenance department staff at EPN headquarters consulted with engineers from Framatome, a private French company that designs, builds, and provides maintenance services for all EDF reactors. By the next day, both short and long-term solutions to this problem had been discussed. EPN staff agreed with Framatome's suggestion that a sufficient, temporary solution would be to place a collar over the pipe where the core weld occurred so as to reduce vibration in the area. Arrangements were immediately made with both Framatome and Nordom, another French company engaged in the maintenance of nuclear power plants, to perform the modification. (Both Nordom and Framatome have ongoing work contracts with EDF, so it was easy to arrange for them to perform the required work.)

Meanwhile, inspections were to begin at the 19 other 1,300 MW plants to investigate whether they, too, had the same problem. Even as this was being done, by July 2 EPN engineers in Paris had identified other systems on 1,300 MW plants which had similar nozzles or welds that could conceivably be prone to the same problem. Their initial analysis indicated that 1,300 megawatt plants had a total of 84 similarly designed nozzles which would now have to be checked for the same problem.

By July 5 problems had been detected on the same safety system at six different plants. Concern over the problem escalated further when a week later an identical problem was found at another plant but on an altogether different safety system. By July 8, a root cause analysis of the water leakage at the nozzle suggested that cracks in the weld were likely due to fatigue caused by the transmission of vibration along the main safety pipe. This vibration was magnified because of the imbalance in size between the main pipe and a connecting pipe on which the nozzle is situated.

The experience in assembling a pipe collar over the faulty weld at Belleville indicated that this type of repair was very time-consuming. Consequently, another temporary solution was designed which involved assembling a support ring to the pipe in order to reduce vibration. This solution was first tried at another plant (Golfech 1). Control tests were designed to determine which of the two solutions (the support ring or the pipe collar) were adequate for solving the vibration problem on a short-term basis. The inspections and tests with respect to the amount of vibration on the pipe had to be coordinated through the EDF division responsible for hydroelectric power. Specialists in vibration are based in that division to monitor the status of EDF dams.

By the end of July, similar problems had been identified at 14 plants involving two different safety systems. Subsequent tests on

two other safety systems could only be performed while plants were in outage. In the meantime, steps were taken to make the necessary repairs at all plants by the end of July, 1991, with most of the repairs completed by the middle of August.

While short-term measures were taken to develop and implement a solution to this problem, the defect raised long-term concerns with respect to vibrations on safety system pipes. EDF had met with French safety officials on several occasions to discuss the implications of these discoveries and their possible consequences. At the request of French safety officials, EDF began a series of tests for vibration on safety systems to determine whether or not the anti-vibration collar solved the problem, how the design of the 'piquage' led to the vibration in the first place, other potential causes for these vibrations, and a more accurate way of assessing the relative safety of the systems. These tests and studies involved several contractors and EDF divisions including Framatome, EDF's Direction d'Equippement (Plant Design and Construction Division), the Direction des Etudes et Researches (Research and Development Division), and the Groupe des Laboratoire (an EDF unit that specializes in equipment tests and measurements). EPN staff in Paris established and led a work group that was responsible for coordinating these on-going studies.

The problem of the piquage was subsequently discussed by EPN's maintenance department in its 1991 annual report. Altogether five

cracked nozzles were detected at four plants on the Spray Containment System and 15 cracked nozzles at six plants on the Safety Injection System. The cost to repair a nozzle by means of a support collar was approximately 7,000 French francs ($1,400) while repair cost for a pipe sleeve was 100,000 French francs ($20,000). As of the fall of 1992, EPN staff were still awaiting the results of the research which was expected to be reviewed by the work group in December. At irregular intervals, EDF held meetings with French safety officials to discuss the status of the research into the nozzle problem.

Addressing the piquage problem at a plant level

In 1991 while EPN headquarters staff were studying the nozzle event and arranging for short-term solutions to be implemented, the real impact of the event was experienced at the plants themselves. For example, at the St. Alban plant after the event at Belleville, tests were conducted during the weeks of June 24 and July 1 in accordance with the directives sent out from Paris. One test on St. Alban 1, which was in full operation, revealed a defect. However, the results of this test arrived late on Friday, July 5 so the decision whether to shut down the plant fell upon the on-call team of operating and safety engineers and the deputy site superintendent. Due to the safety implications, the decision was made to shut the plant down, and Paris headquarters was so informed.

Since EPN had already contracted on a centralized basis with Framatome and Nordom to correct the defect, arrangements were immediately made for a repair team of two welders and an engineer to perform this work at St. Alban. Since there are some small differences in plant configuration and construction, Framatome and Nordom engineers were in regular communication with their counterparts in Paris to discuss ways of adapting the solution of the pipe collar to the particular circumstances the team faced. At this stage some of the information sharing began to break down.

Up to this point, information about the defect and its solution had traveled between plant sites up to Paris headquarters and back down to plant sites. Information was also shared between plants about the potential for this problem to exist. However, as work teams began to correct the problem, communication continued to flow vertically rather than horizontally between repair teams at or between plants. The latter would have enabled lessons to be exchanged about how best to expedite the solution, thus reducing the cost of making the repair, and more significantly, reducing the time the plant would be in outage. Altogether, it took ten days to correct the defect at St. Alban 1. Lost production was valued at one million French francs a day for a total loss of 10,207,000 French francs ($ 1.7 million dollars). This loss was attributed to the 'parc' (EDF's network of plants) not to St. Alban, since the defect stemmed from a flaw in plant design, not operations.

Little information was shared between repair teams of the two different contractors or the repair teams and EDF staff, either at St. Alban or at EPN headquarters. However, information was continually shared among EDF staff. For example, on July 10, less than three weeks after the event at Belleville, a meeting was organized in Paris with representatives from each of the affected plants, as well as headquarters engineers who had been studying this problem. It was through their discussions that both short and long-term solutions to the problem of the piquage were selected. Since there were differences of opinion over the best method to solve this problem, control comparison tests were designed as ways to compare the relative benefits of the brace versus the collar solution.

Whatever inefficiencies may have occurred due to some constraints in information flow, they pale in comparison to the disastrous consequences that might have occurred had St. Alban's nozzle defect gone undetected. In fact, the same problem was detected at St. Alban 2 which was in outage at the time. Repairs there were made prior to start-up as a maintenance task completed during outage. St. Alban also benefitted from EPN headquarters efforts to design a short-term solution and arrange open work orders with contractors.

III. ORGANIZATIONAL LEARNING IN NUCLEAR POWER OPERATIONS

The event of the piquage at EDF shows how an organization uses routine processes to recognize problems or defects and acts upon them, thus learning from past performance. Nuclear power plants benefit from their use of a technology whose performance can continually be monitored. Their reliance on material components and systems provides a basis upon which tests and measurements may be taken to assess operational status and accumulate knowledge about performance.

Some scholars (Perrow, 1984; Roberts, 1990) talk about the dangers in organizations like nuclear power plants because of the implications of faulty operations. The term "high reliability organization" has been coined to reflect the necessity that these organizations be reliable because of the disastrous consequences of system failure. However, from another perspective, nuclear power plants, as tightly coupled, material systems, form environments in which problems can be identified by comparing actual to ideal or regulation-specified operations. Through continual testing there is also the possibility of reducing the time between the existence of a defect and its discovery. This type of intervention can lead to the correction of latent defects before they actually affect plant performance.

System engineers have addressed the concern for safety by building in redundancies so that should one system fail, another would be operational. In nuclear power plants defects in system components (pumps, valve, pipes, hoses, etc.) are detectable. The key in nuclear operations is to correct or minimize defects so that their consequences are insignificant. Learning comes from identifying defects and then developing and applying a shared solution across the organization.

In many other industries where there is a time lag between a poor decision being made or a defect being created and its identification as such, it is difficult to make the link between poor performance and its root cause. Organizations where there are standardized indicators of performance, where measurements are taken continually, and where poor performance can be attributed to underlying causes engender conditions where learning based on past performance is feasible. These characteristics establish preconditions for organizational learning but they do not in themselves ensure it. Organizations must establish their own processes whereby they may act upon these preconditions so that learning (and all its phases of knowledge creation, dissemination, and utilization [Huber, 1991]) may take place. By building into the very culture and structure of the organization a routine focus on error detection and correction, companies can ensure a continual improvement process, the aim of any performance feedback system.

At EDF, organizational learning takes place in a company context where staff participate in processes and structures that facilitate the sharing of information. The problem of the piquage shows how information is exchanged across the company and how generic defects can be solved in an expeditious fashion through a commonly applied solution. In France there is public pressure to maintain safe operations while meeting ever rising standards of efficiency. EPN personnel meet this demand by managing France's nuclear plants not as individual units but as a collective "parc" or network of organizations engaged in a common concern.

It is not possible to actually determine how effective is the "retour d'experience" at EDF since no one really knows how many latent defects or problems are awaiting to be uncovered. What can be researched is how detected problems, like the piquage, lead to knowledge acquisition and operational improvements. Given the complexity of nuclear power systems, the search for reliable solutions may require a long-term time commitment which can lead to significant delays in correcting problems. There also appears to be more glamour in detecting defects and correcting them with novel, short-term solutions than making long-term investments in learning. There is a danger that the learning system, by focusing staff attention on error detection, reduces staff focus in designing the most efficient solution.

The learning system at EDF is also limited in that the predominant focus is on the failure of tangible components within the given system as it is designed. In that sense problems like the piquage only lead to single loop learning (Argyris & Schon, 1978). Defects caused by human factors are harder to detect and solve, and generic problems that demand critical questionning of underlying technical or cultural assumptions cannot be addressed by staff responsible for real-time operations. To describe learning in an organization like EDF requires a broader view of learning as a collaborative venture among staff and line functions. Also the capacity to identify operational defects should not be equated with an actual increase in efficiency.

REFERENCES

Argyris, C. and Schon, D.A. 1978. Organizational learning. Reading, MA: Addison-Wesley.

Huber, G. 1991. Organizational learning: The contributing processes and the literature. Organization Science 2, 88-115.

Perrow, C. 1984. Normal accidents. New York: Basic Books.

Roberts, K. H. 1990. Some characteristics of one type of high reliability organization. Organization Science 1, 160-176.

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